THE GEOMETRY OF THE JUNIOR HIGH SCHOOL.

The educational world is, like the industrial world, in a state of unrest. Many are seriously questioning the values of some subjects that have long been included in the curriculum and the educational literature of the day contains numerous suggestions for the relief of real and assumed educational ills. It is important that teachers and administrators should be as careful to discover wherein new theories are unsound as to discard the errors of the past. We must strive to keep our bearings in the midst of the confusion of the day.

Efficient teachers of mathematics will admit that the subject is not taught in an ideal manner. No subject in the entire curriculum is so organized or so taught. The mathematics of the school has not been sufficiently related to the mathematics of life outside the school. The roots of the mathematics taught in the school have not been sufficiently "imbedded in the soil of reality." It is not probable that a subject which the race has developed through the ages and which is intimately related to so many of the necessary activities of civilized man will be discontinued in the schools. The iconoclast who uses mathematics in the tabulations wherein he seeks to prove that mathematics is useless, cannot destroy the subject and he does not wish to improve it. Revisions, eliminations, and readjustments which are necessary will be made as the result of the judgments of those who are honestly seeking to improve the courses.

The rapid increase in the number of junior high schools is one of the most significant facts in recent educational progress. The history of education is replete with movements that have given promise of permanence but many of the reforms have proved to be ephemeral. The organization and development of the junior high school "seems sufficiently in accord with experience and with common sense to give some promise of permanence and hence to justify serious consideration."

A subject which is related so intimately to the needs and the interests of mankind as mathematics must be given a

prominent place in the curriculum of the junior high school. The subject may be so taught as to emphasize its application to the every day problems of life outside the school and, when so taught, it loses none of the charm which has attracted to it some of the best minds of the ages. The efficient teacher need not fear that mathematics will make a weaker appeal to boys and girls as a rsult of present adjustments, eliminations, and shifts of emphasis. The more firmly "the roots are imbedded in the soil of reality" the stronger and more attractive should be the appeal.

The course in mathematics in the junior high school should be a unit. It should be the best possible course for the pupil whether he does or does not continue through the senior high school. The course should prepare the pupil to meet his assured mathematical needs. The course should not be vocational in the narrow sense. It should awaken vocational interest but the junior high school period is not the time to develop skill in production. The course should develop the pupil in a broad way. It should be the basis of the mathematical training for his life career. It is not possible to anticipate all of the situations which will confront a pupil. The essential thing is, in the words of John Dewey, to give not the actual situations to be met later, "but the *power* to meet them." The mathematics of the junior high school should be so organized and taught that it will prepare the pupil to meet successfully the mathematical situations with which he is confronted while still a pupil in the school and with which he is mostly likely to be confronted outside the school. Moreover, the course in the junior high school should lead the pupil to a mastery of certain parts of the great subdivisions of mathematics. Bits of arithmetic, algebra, geometry, and trigonometry here and there are not satisfactory to either pupil or teacher. When the subject is presented in such a way the pupil is likely to leave the course with a confused knowledge of the whole and without that consciousness of mastery which is his right.

The first half of the seventh school year should be devoted to the study of arithmetic. This subject relates to the immediate mathematical interests of the pupil; it connects directly with the mathematics that has preceded, and it will enable the

pupil to maintain or increase the efficiency in computation which he has acquired. The work in arithmetic should be organized about certain large topics of practical value which challenge the interests and meet the needs of the pupils. Such topics as the following are admirably suited as cores about which the various phases of the work may be centered: The Arithmetic of the Home; of the Store; Industry, and the Bank.

The latter half of the seventh school year should be devoted to constructive and intuitional geometry. The subject is more concrete than algebra; it admits of more simple illustration; it relates directly to the arithmetic that has preceded; it challenges the interest of the pupil; and it may be made very practical. Some knowledge of geometric forms and mensuration is desirable in almost every walk of life.

The course in geometry suggested by outline in the following pages is now used in some of the best junior high schools of the country, and numerous teachers and administrators are witnesses to the fact that the course so organized may be taught in such a way that not only is the interest of the pupil challenged and held but the pupil is introduced to one of the great subdivisions of mathematics. He is enabled to understand and to appreciate mathematics as a tool, and to develop that feeling of power and of mastery which is his right and privilege. Such a course meets the dominant interests of the pupil and is adjusted to his development. It enables the pupil to develop power and the habit of interpreting more fully the quantitative relationships which exist.

Course in Geometry.

Many years ago when men began to study about forms they used to decorate their walls with pictures showing the shapes of objects. Later they drew plans of homes and temples and drew pictures of animals and human beings. As land became more valuable they became interested in measuring fields and building materials, and it became necessary for them to consider position and to locate places on the earth's surface. From early times men have been interested in ideas of form, size, and position. The three questions which we frequently ask about an object form the bases of constructive and intui-

tional geometry. These three questions are: What is its shape? How large is it? Where is it?

The pupil is already more or less familiar with many of the common geometric figures such as the square, triangle, circle, arc, and cube. He should learn early in the course the various kinds of angles, triangles, quadrilaterals, and other common polygons and he should be taught to observe these forms in the school room, on the school-grounds, and elsewhere in his daily activities. He should be taught to use simple drawing instruments such as the compasses, the ruler, the protractor, and the right triangle in the construction of the various kinds of triangles and polygons and in the making of various geometric patterns and designs. He should be led to discover by experiment and observation the truth of some of the most important propositions to be proved later in demonstrative geometry. He should be taught to think clearly about form, size, and position, and to *see* mathematics in nature and in objects of human construction. The following outline will be suggestive:

OUTLINE OF CONSTRUCTIVE AND INTUITIONAL GEOMETRY FOR THE LAST HALF OF THE SEVENTH SCHOOL YEAR.

The Geometry of Form. What Shape Is It?

Angles and triangles; quadrilaterals; common polygons.

Use common drawing instruments, such as the compasses, the ruler, the protractor, and the right triangle.

Construct various kinds of triangles and discover the angle sum of any triangle.

Construct perpendiculars and bisectors.

Construct angle equal to a given angle and triangles with various parts given.

Construct parallel lines and develop the principal theorems related to angles formed by a transversal which cuts parallels. Use the protractor and paper cutting.

Make various geometric designs by means of simple constructions.

Draw to scale. Apply to the problems of the builder, the farmer, the engineer, the designer, and the geographer.

Similarity of shape. Similarity in photographs.

The pantograph. Symmetry.

Provide numerous practical problems including much outdoor work involving the applications of the preceding. Introduce each topic in such a way as to challenge the interest of the pupil and to appeal to him as worth while.

The Geometry of Size. How Big Is It?

Introduce numerous practical problems involving estimates and measurements of heights, distances, and areas. Estimate dimensions of school room, school grounds, etc., and check estimates by measurement.

By use of congruent triangles, measure the heights of such objects as trees, buildings, and flagpoles, and the width of rivers; and check results. Encourage pupils to suggest problems which appeal to them as practical. The pupil is delighted to find that he has sufficient mathematical knowledge to determine inaccessible heights and distances. He has the knowledge and he should feel the power.

Introduce the study of areas by the use of squared paper.

Develop the formulas for the areas of the common plane figures and apply to numerous practical situations such as those which most commonly confront the pupil, the farmer, the housewife, the engineer, the business man, and the artisan. Continue the emphasis on outdoor work.

Introduce ratio and proportion and use proportion in the determination of heights and distances involving similar figures.

The Geometry of Position. Where Is It?

Introduce this subject by problems, such as locating the proper position for second base on a baseball diamond after the other bases have been located.

Challenge the interest of the pupil by introducing problems dealing with attempts to locate buried treasures.

(*a*) Develop and apply practically the method of determining points equidistant from two given points; (*b*) distance of a point from a line; (*c*) points equidistant from two lines; (*d*) points at a given distance from a given point.

The applications of the geometry of position are numerous and interesting. The pupil may be led to appreciate that he is acquiring knowledge that is necessary to the solution of many problems of a most practical and interesting type.

Experience seems to indicate that the arithmetic and the constructive and intuitional geometry of the seventh school year should be followed during the first half of the eighth school year by algebra. The introductory course in algebra should no more be formal than the introductory course in arithmetic should be a formal course in computation. The algebra should be such as every boy and girl should become familiar with at this time. It should not be burdened with technical phraseology but it should be utilitarian in the largest sense. Some knowledge of the formula is needed in reading many books and articles, the graph is used in many lines of business, the equation is helpful in manipulating formulas, and negative numbers are so commonly used as to be a necessary part of the equipment of every reader of current literature as well as of scientific books.

During the last half of the eighth school year those practical topics of arithmetic for the study of which the pupil's maturity has prepared him should be studied. Among these topics the following should be included: The Arithmetic of Trade, Transportation, Industry, Building, Banking, Home Life, Farming, Civic Life, and Investments.

It is not improbable that the ninth school year will eventually be the last year of *required* mathematics. It is very desirable that the pupil have some knowledge of formal mathematics.

During the ninth school year most of the time should be devoted to the study of elementary algebra and geometry. Algebra should be placed first as the student is familiar with it and needs to use it in his other mathematical work. By omitting the non-essentials, the pupil can complete algebra through quadratics during the first half of the year. The trigonometry of similar triangles may be introduced.

There should be a gradual introduction to demonstrative geometry. Independent deductions should precede formal proofs and a large number of practical exercises should follow

each proposition that is studied. Extreme formality of treatment should be avoided and originality, clearness, and conciseness should be emphasized. The formality of some introductory texts in demonstrative geometry tends to discourage many pupils. The pupil should recognize the necessity for a proof and he should understand the nature of a geometric proof. He should be taught to prove a number of the most important theorems such as the theorem of the angle sum and the square on the hypotenuse. The exercises should be simple in nature but they should encourage that independence of mind which is more valuable than a knowledge of a conventional number of formal propositions.

Experience has shown that pupils of the ninth school year enjoy demonstrative geometry when it is properly motivated and presented. Pupils do not find the subject difficult. Many of the important theorems of the first two books can be proved and applied by the pupils. Practical applications which are within the understanding and the experience of the pupils are numerous. The initiative of the pupils is encouraged.

The student who has followed such a course as is here outlined has studied the elements of mathematics and is in a position to know whether he cares to pursue the subject further. The door of the science has been opened to him, and he has entered. He is in a position to proceed further, if he cares to do so. The course is arranged in psychological sequence and it is utilitarian in the best sense. The course is so organized that it gives the pupil that feeling of accomplishment and mastery which is essential. It articulates the various subjects and forms a natural transition between the mathematics of the lower grades and that of the senior high school.

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